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APPLE SCAB.

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Investigations by the Department of Horticulture of the University of Illinois upon the disease commonly known as Apple Scab were published in Bulletin No. 54. These studies were mostly connected with preventive measures and the conclusions were mainly based upon field experiments. The present publication records the results of botanical studies made during the years 1898, 1899, and 1900.

Scab is a disease of the leaves and fruit of apples (Fig. 2) caused by a parasitic fungus botanically named *Fusicladium dendriticum*. Many fungi possess at least two stages; namely, a summer or temporary spore stage adapted to spread the disease during the growing season of the host, and a winter or permanent stage adapted by greater protection afforded the spores to carry them through the winter and thus insure the infection of the host

again the following year. These stages usually differ greatly in appearance and may occur on different parts of the same host and at different times of the year, or they may occur on entirely different plants, thus causing one to regard them as two distinct species until their life history has been thoroughly worked out.

The apple scab constitutes the temporary stage of a fungus and one of the points of investigation was to determine if there were a permanent stage connected with it, or, if not, how the fungus passed the winter. Accordingly careful examinations were made of the twigs and old fallen leaves during the fall and spring with the result that on the latter in the spring there was found a fungus that appeared to be the permanent stage. Germination of the spores of this in Van Tieghem cells in 1898 showed that the mycelium from them could give rise to spores similar to those of the scab stage. This fungus had been long known to botanists but under an entirely different name, being called *Venturia chlorospora*.

At this time it was not known to the writer that the latter had been suspected by others as the permanent stage of the apple scab fungus. An examination of literature, however, showed that Goethe as early as 1887 had suggested the relationship of the scabs of pears and apples to mature stages on the dead leaves; that Brefeld in 1891 figured a temporary spore stage obtained from a Venturia on pear that was similar to the leaf scab of that plant; and that Aderhold, 1894 and later, had made a very comprehensive study of the scabs of apple, pear, and cherry and had connected them with species of Venturias that develop on the dead leaves of these hosts.

From the results of these and the writer's investigations there is no doubt that apple scab is merely a parasitic summer stage of a permanent saprophytic fungus occuring on the fallen leaves. It also appears to be this latter form that is largely (in its immature condition) responsible for carrying the fungus through the winter. At least the writer has been unable to find any satisfactory evidence that the scab stage persists on the young twigs, as has been stated by some investigators, and by means of a new crop of scab spores in the spring spreads the disease to the young fruit and leaves. Neither was there found any evidence that the old spores lived over the winter on the fallen leaves, or that the mycelium in these gave rise to a new crop for spring infection.

Injury.

This is a common disease of the apple wherever grown though the amount of damage inflicted may vary considerably in different

localities and especially during different seasons. It occurs on the leaves usually in distinct, small, circular, olive colored areas and in time is likely to cause more or less puckering of the tissues or even killing the plant cells beneath. When very vigorous on young leaves it may cause them to turn yellowish and drop from the tree, though usually the leaves remain attached until fall when they may be shed somewhat prematurely. By these means the fungus interferes with their function as food producing agents and thus more or less indirectly affects the general health of the tree.

On the fruit it produces the "scabby" spots familiar to everyone. These are roundish, olive-colored, roughish areas usually about one quarter of an inch in diameter, or by coalescence more or less covering the surface of the apple. When the very young fruit is very badly infected it may cause distortion and interfere with the normal development in size, or, if severe enough, cause the young apples to fall from the tree. The injury of the fungus is thus direct and easier of determination.

By these direct and indirect effects the quantity of fruit produced may be considerably lessened and the quality made inferior. It is hard, however, to give the exact loss caused by such a disease unless one carries on careful experiments to determine quantity and quality of fruit produced from sprayed and unsprayed trees of the same variety grown under otherwise similar conditions during a series of years. Most estimates given from such losses are mere guesses. There can be no doubt, however, that thousands of dollars are lost each year even in this state alone, and that during certain years the loss is much greater. Professor W. J. Green, of Ohio, who has carried on careful spraying experiments against scab gives the following as results in an orchard in 1897: "The average per sprayed tree was 6.75 bushels and of the unsprayed 2.42. Fifty sprayed trees produced 4.33 bushels of apples more per tree than the unsprayed, which was secured at a cost of not more than 20 cents per tree. In the case of the Northern Spy and Baldwin the actual profit derived from the treatment was more than $5.00 per tree."

This fungus, on the whole, seems to be more injurious in the states of the Mississippi valley than in some of the eastern coast states. Its injury, as stated before, also varies considerably during different years. This is largely due to weather conditions. It does most injury those years which have unusually wet springs, especially if cold damp weather occurs during the unfolding of the leaves. Its severity also seems to bear some relation to the amount of the Venturia stage that has developed on the old leaves.

There appears to be no such thing as a scab-proof variety. Various writers have recorded observations showing that certain varieties have been more severly injured than others and there is no doubt that this is the case. It is very likely that such differences are due in large part to the thinner or more easily punctured cuticle of the scabbier varieties. The writer has also observed that scab is a lover of neglected orchards—orchards which have not been properly sprayed, pruned, or cultivated—and that it seems to be less abundant on very young trees, especially where such trees are isolated. This latter is probably due to less favorable conditions for original infection.

Scab has been known to botanists as a fungous trouble of the apple since the first part of the nineteenth century. Schweinitz, one of the first collectors of fungi in this country, found it at work on Newton Pippins in New York and Pennsylvania in the early thirties of the past century. Curtis records it as common on apples in North Carolina in 1867, and other early writers have listed it from various states.

The earliest reference to its appearance in this state that has been found is a note in the Report of the Illinois Horticultural Society for 1863, page 119, where Mr. Murtfeldt, of Ogle County, reported Carolina Red June, and Early Red as small and inclined to scab. Professor Burrill in 1883 writing of it as an apple scourge in the Mississippi Valley, said in part: "Everyone must have noticed last year a peculiar shriveling and curling of the apple leaves, beginning in many cases soon after the bursting of the buds in spring time and continuing more or less during the season. * * * The apples have been, in numerous instances, so scarred and spotted as to be practically worthless, except for stock or cider. * * * In Champaign County the Early Harvest apples, among others, were divided half way to the core, or even deeper, by several irregular fissures, leaving knobby lobes, more or less covered by a layer of blackened corky tissue." The writer in his collecting in recent years over the state has always found apple scab more or less common and often doing serious injury.

Prevention.

It is not the purpose of this bulletin to go into detail concerning the prevention of this disease. It is known, however, that the injury can be stopped largely by proper attention to spraying. Since the experiments started under the direction of Galloway, of the U. S. Department of Agriculture (by Goff in Wisconsin and by Taft in Michigan) there has been much written by various station

workers concerning the prevention of scab through spraying. As a result of these activities Bordeaux mixture has been found the most valuable fungicide. The present tendency is to use it made as follows: 4 lb. copper sulphate, 4 lb. fresh lime, and 50 gal. water. The copper sulphate may be dissolved in hot water, the lime slaked in a suitable quantity of water, the two then being mixed together and strained into a barrel containing the remaining amount of water.

Much of the success in the use of a fungicide depends upon the proper application and the time of spraying. The trees should be *thoroughly* sprayed. The first application should be made soon after the leaves begin to unfold, followed by a second soon after the petals begin to fall and by a third in less than two weeks if the season has been favorable for the development of scab. Later sprayings are apt to burn the foliage and russet the fruit and so are not very desirable. Some writers advocate two sprayings before the petals fall, the first with the swelling of the buds and the second after the leaves have expanded but before the petals are open. Winter spraying with a strong solution of copper sulphate has also been found to retard the first appearance of scab, but it is questionable if it is worth the extra expense and trouble if the first treatment with Bordeaux mixture is made promptly and thoroughly. In case the codling moth is injurious Paris green, at the rate of 1 lb. to 200 gal. of the Bordeaux mixture, may be added for the second and third sprayings.

Besides spraying proper attention should be given to pruning, as properly pruned trees are more easily and cheaply sprayed and also because unpruned trees afford greater protection against quick evaporation of moisture and thus so far favor infection by scab. The same holds true of proper cultivation, since orchards neglected in this respect offer greater protection to the fallen leaves, which, as we have seen, are the means by which the permanent stage develops and produces infection in the spring. No careful experiment of raking together and burning all of the fallen leaves from an orchard has been carried on and so nothing definite can be said of the advantage of this procedure. However, in a small plat in an orchard from which the leaves had been so removed the first appearance of scab on those trees seemed to have been retarded and reduced. Such work to be of any value should be done very thoroughly in the autumn after all of the leaves have fallen.

Fusicladium or Parasitic Stage.

Time of Appearance, etc.—Scab makes its first appearance early in the spring, usually soon after the leaves begin to unfold,

and it is while these and the fruit are in a young condition that the fungus can best infect them. While it is to be found from the first appearance of the leaves until they drop off in the fall, there are two periods of greatest activity in spreading, one early in the spring and of the greater importance and the other in the autumn. This latter infection does little damage but is important because it is probably largely responsible for the development of the mature stage.

During the years 1898 to 1900 a careful watch was kept of apple trees to determine first appearance, manner of infection, and relative abundance of scab. In 1898 the first sign of scab was seen on May 2d, though from its condition then it probably made its appearance several days earlier. At this time the oldest leaves had not reached their full size. On some trees the scab appeared more abundant on the lower than on the upper branches; it was much more abundant on those leaves developed from flower buds than on those from the later purely leaf buds; it was most abundant on the lower surface in the vicinity of the midrib. This latter condition showed that the first infection had taken place very early, before the leaves were entirely unfolded. As apple leaves are folded on the midrib as an axis with the upper side within and the edges somewhat involute, the lower surface next the midrib is the first and most exposed part. The fact that the scab was most abundant on the leaves produced from flower buds suggests the possibility of insects as carrying agents for the spores, or it might be that such leaves being the first to unfold merely show the scab earlier on this account. On the very young fruit the scab often appeared at one side and toward the blossom end. The spring was cold and damp and as a result scab was much worse this year than either of the other years. There was also found an abundance of the Venturia stage on the old leaves before and during the first appearance of the scab.

In 1899 a very careful examination showed the first scab on May 5th, on a very few leaves. This year it was slow in appearing and the oldest leaves escaped more than the later which were developed during a more moist period. The scab also appeared much more commonly on the upper sides of the leaves. The early spring was unusually warm and dry and therefore very unfavorable for the spreading of the disease. The Venturia stage was also much later in developing and many perithecia were found which seemed never to have matured their spores. This stage was much scarcer than it was the previous year.

In 1900 the first sign of scab was found on a crab apple on

May 11th. This tree had been badly infested the previous year, and when first examined only two or three scabby leaves were found. The fungus did not make a general appearance in orchards until quite late, the latter part of the month. In one orchard examined on May 21st no scab was found on a certain tree. This was examined again on June 4th and found badly scabbed on most of the lower leaves except the oldest. This tree had branches that reached down to the ground. The orchard was uncultivated and that spring the Venturia stage had been found fairly common on the old leaves. The following counts of leaves taken as they came show the relative abundance of scab on the lower and upper branches of the tree :

	Total leaves examined.	Scabby.	Total scabby spots.
Branch in top	118	3	3
Branch on ground	99	53	520

A later examination showed that the scab had spread somewhat in the top of the tree. These conditions seem clearly to indicate that the original infection had come by means of the lower branches from the Venturia stage on old leaves on the ground.

Often the primary infection seems to be slight and in such cases it is from the spores developed from these that the scab becomes spread over the tree. Sometimes it seems to appear on one tree and spread from this to the others. Very often trees show no difference in the development of scab on different parts.

On the leaves.—Scab generally occurs in roundish colonies about one quarter of an inch in diameter (Fig. 4). These may remain entirely distinct or run together so that they loose their individuality. This is often the case where they are crowded along the prominent veins. It is a common thing for the colonies to start over the veins as if these offered more favorable places for infection or for growth. The spots have an olive green color and under a magnifier are seen to consist of distinctly toothed and branched fungous strands (apparently on the surface of the leaf) that radiate from a common center.

Sections through scabby spots seen under the microscope show the mycelium as a single thread in thickness (but no doubt several lying side by side) creeping over and closely applied to the top of the epidermal cells but beneath the cuticle and narrowing down at the end to a point by means of which it separates the cuticle from the epidermal cells (Fig. 7). The cuticle on the young leaves is not very easily made out but on the older ones where it has attained some thickness it becomes more evident. By this manner of developing the fungus is protected on the outside by the cuticle while

by being directly applied to the cells on the inner side it is able to take nourishment by absorption; no haustoria were found. The mycelium sometimes pushes down somewhat between the epidermal cells but very rarely, if ever, goes deeper in green leaves.

When this subcuticular mycelium, which averages 4 or 5 μ in diameter, is ready to form spores it divides up into more or less distinct, hyaline, roundish cells about the same diameter as the threads (Fig. 8 and 9). Often there is but a single layer of these, but sometimes, especially above veins and woody tissue, this subhymenium is two or more cells deep. From these are developed upright at first bluntly lanceolate to ovate shaped cells, or conidiophores, that penetrate the cuticle (Fig. 6). They have a thicker, reddish, outer wall and a very thin hyaline inner one, and occur in groups of greater or less extent, generally touching each other a their broader bases but separated at their apices.

The spores are formed by the protrusion from the apex of the conidiophore of its inner wall and contents as a hyaline roundish body, with more or less of a distinct base (Fig. 7 and 8). This, when fully grown, forms the lanceolate, acute, reddish olive colored spore. When mature the spore is pushed off by the development in a similar manner of a second one. Each time a spore is formed, however, the conidiophore is lengthened by the remaining short basal part. This at first consists of only the hyaline inner wall, but develops with the spore the outer colored wall. By this means the conidiophore is not only lengthened but given a banded appearance something like short joints of an extended sliding tube (Fig. 10). The conidiophores thus in time become cylindrical with short swollen bases, their final length being determined by their age and the character of the season as affecting the number of spores formed. The old conidiophores sometimes develop a septum or two. On an apple leaf gathered the latter part of June there was seen a conidiophore that had developed ten of these spore bands.

The scab colony soon assumes its full size and the chief change during the season is the development of some new conidiophores and the growth of the old ones. Toward the end of the season the cells of the subcuticular mycelium may increase somewhat in size and become more or less tinted, but the chief change in this respect comes after the leaves fall and their tissues die. Earlier or later in the season the action of the subcuticular mycelium, possibly in part through pressure, but probably largely through irritation, causes a more or less complete collapsing of the epidermal cells. This no doubt causes the puckering often seen on badly scabbed leaves.

Scab spores are chiefly lanceolate, varying from narrowly

lanceolate to ovate (Fig. 16). They are widest near the base which tapers somewhat to the truncate end or former point of attachment. Toward the usually acute apex they taper gradually, but are sometimes slightly constricted giving a somewhat fiddle shape. Usually they are one-celled, though a septum is somtimes developed near the center. In color they are reddish olive and in size generally vary from 12—22 μ in length by 6—9 μ in greatest width.

On the Fruit.—On the apples the fungus produces the so-called "scabby" spots (Fig. 5) which are usually $\frac{1}{8}$ to $\frac{1}{3}$ of an inch in diameter though by coalesence they may more or less cover the surface. These develop vigorously on the very young fruit but after the apples obtain some size their growth is slow and usually there is little danger from further serious infection. This is due to the very thick cuticle developed on the fruit. The scab colonies when fresh have a dark olive green color with, usually, a narrow lighter border. The cuticle of the apple becomes ruptured and flaked off, and in time the olive colored fungous cells are also more or less worn away so that the color may assume a reddish brown shade due to the exposed dead tissues.

Sections under the microscope show that the development of the fungus is somewhat different from that on the leaf. This and the microscopic appearance caused botanists originally to consider the forms on the leaf and fruit as two distinct fungi. The difference is not so great as it appears and is due chiefly to the greater development on the fruit of the subcuticular mycelium which in the more advanced stages often forms a tissue many cells deep (Fig. 15d). This vigorous development seems to be due to the very thick cuticle (Fig. 13c) which evidently makes it much more difficult for the penetration of the fungus to the outside (Fig. 14) and as a result there is formed quite a tissue before the conidiophores are pushed through and developed. While at first this subcuticular mycelium is made up of the small, roundish, hyaline cells these grow in size and especially at the outer surface become more or less colored like the conidiophores. In the apple stored over winter, shown in Fig. 15, these cells had all become thus colored and gave the appearance of a resting stage of the mycelium. The action of the fungus often causes more or less of a collapsing or flattening of the host cells beneath and this results in the formation of a sort of corky tissue (Fig. 12b) which affords protection to the plant against evaporation and the entrance of other fungi.

Scabby apples that have remained outdoors all winter, because of the general rotting produced by other fungi, show little evidence

of scab and there is no ground for supposing that they are the means of any spring infection. Stored scabby apples, having been protected against decay, show some evidence that the mycelium at the margins of the colonies is still alive and capable of producing a few spores.

On the Twigs, etc.—It has been claimed by some botanical writers that the apple scab fungus also developed on the young twigs and by this means was carried over the winter and by the production of scab spores in the spring caused the infection of the leaves and fruit. During the three seasons the writer has had the fungus under observation very careful examinations have been made of the twigs at different times of the year to determine if this was the case. In only one instance was the fungus ever found growing on the branches and that exception was a badly infected crab-apple which had several twigs of the current year's growth considerably infected. On this tree the scab was also found abundantly on the leaves and petioles and in a few cases on the pedicles, calyces and styles. The tree was thoroughly examined again the next spring but no sign of the fungus was found on the twigs. It is not uncommon for the scab to occur on the leaf petioles but it never seems to develop down upon the twigs in such cases. In the spring, before the appearance of the fungus, loose spores have been scraped from the twigs, but it appears hardly probable, if alive, that these are the means of any considerable infection.

Germination of Spores.—Fresh spores placed in water in Van Tieghem cells generally show some beginning to germinate inside of twelve hours and by the end of twenty-four hours these may have germ-threads several times the length of the spores (Plate I, Fig. A). The germ-thread may emerge from either end or the sides of the spore but it most frequently comes from the pointed or apical end. Usually the germination does not proceed further than to form a simple, rarely slightly branched, hyaline, septate thread somewhat narrower than the spore and often many times its length.

In apple leaf broth or apple leaf agar the germination is much more vigorous, the germ-threads often becoming branched and more elongated, forming a slight mycelium. Often the ends of the threads or branches become somewhat swollen, more closely septate, and develop short, more or less knobbed, or irregular branches that when cut off by a septum in some instances have a spore-like appearance. These peculiar tips usually become tinted like the spores (Plate II, Fig. A). Their nature is not very evident. They may possibly be only a sort of resting condition of the mycelium since

frequently they send out more slender hyaline threads as if in germination (Plate II, Fig. C) and these again may develop similar tips. Occasionally in these cultures the mycelium formed true scab spores. These are usually produced on short hyaline side branches not especially differentiated as conidophores. The first spore formed may be pushed aside by the development of a second and often several are seen detached in the neighborhood. These spores are colored and otherwise similar to those produced in nature (Plate I, Fig. D).

Artificial Cultures.—The writer usually found it rather difficult to obtain cultures of the scab fungus from Petri dish separation cultures of the spores. This was partly due to frequent development of surface bacteria over the agar, especially on fresh apple leaf agar, but chiefly to the very slow development of the scab colonies compared with those of the molds whose spores had been introduced. It usually took from two to four or five days before the scab colonies could be detected by the naked eye. These then showed as very small lax growths entirely embedded in the medium but with time increasing in size and growing somewhat into the air. These colonies when very young could be traced down to the spores. Figure 17 shows in part the mycelium of one of these colonies still attached to the spore. Such colonies while young were transferred to test tubes of old apple leaf agar, new apple leaf agar, beef broth agar, beef broth gelatin, beef broth, beef broth corn meal, old apple leaves, and young apples. The growth in these media differed somewhat, chiefly as follows:

On Old Apple Leaf Agar.—The colonies were about ¼ to ½ inch in diameter and composed of a very prominent dense growth of dirty white threads into the air. Spores were rarely found and these disappeared through germination (Fig. 23).

On New Apple Leaf Agar.—The chief difference between this and the above was the more prolific development of spores and the somewhat slighter growth of threads into the air.

On Beef Broth Agar.—This medium being lighter colored than either of the above showed a dark growth in the agar. There was also a slight growth of dirty white threads in the air. Spores were produced somewhat, at least at first. (Fig. 22).

On Beef Broth Gelatin.—The growth in the medium was very dark and in striking contrast to it, while the growth in the air was very slight. Spores were found but usually disappeared through germination. (Fig. 25).

In Beef Broth.—The growth was confined to the liquid or sides of the tube at surface and was similar to that in the gelatin. (Fig. 24).

On Beef Broth Corn Meal.—On this medium the growth most nearly approached the appearance in nature. A dense, short, olive green felt developed on the surface with no growth of dirty white threads in the air. Spores were produced very abundantly and did not disappear through germination. (Fig. 26).

On Young Sterlized Apples.—The growth usually was not very vigorous and was chiefly at place where agar was introduced with the mycelium. In some cases the dirty white threads spread out over the apple but caused no scab like appearance.

On Old Sterlized Apple Leaves.—The growth here was also chiefly in the region of the introduced agar forming more or less of a prominent tuft of dirty white threads which ran out somewhat on surface of leaf (Fig. 21). Growths on old leaves were tried in the hope that the Venturia stage would be developed but were not successful in this respect. While these cultures were unsuccessful, in the case where lately fallen apple leaves containing fine colonies of scab were placed in test tubes on moist cotton plugs and left until the next year the Venturia perithecia were found abundant though immature.

The mycelial threads of cultures are first hyaline but in time become tinted especially those in the medium or against the glass of the test tube where they often assume a dark olive green color. They vary in diameter chiefly from 2½ μ to 5 μ and have at first uniform or vacuolate protoplasmic contents (Fig. 19), but in time are apt to be more or less filled with highly refractive granules of varying sizes (Fig. 18). In the young threads the cells are comparatively longer than in the older, broader ones. In the latter there may occur circular swellings as if due to vigorous osmotic action (Fig. 20; Plate II, Fig. Bc). In old dried out cultures highly refractive spore-like bodies, which may possibly have served as chlamydospores (Plate II, Figs. E, F) were sometimes found.

Artificial Infection.—Because of the general presence of scab on apple trees artificial infection of leaves out doors is not safe unless on isolated trees not liable to develop scab. Most of the experiments tried were with one or two year old seedlings planted in crocks and kept in doors at a higher temperature than the outside. In such cases the spores were usually sprayed in water on the leaves, (especially when they were very young) and the moisture prevented from evaporating by covering the trees for a few days with bell jars lined with moist paper. For some reason it was found rather difficult to infect the leaves of such trees, though the conidial stage of the powdery mildew had no difficulty in producing natural infection. Out of the various trials made at different times less than half of the trees produced leaves with scab and never with any abundance. In one instance where very young leaves were sprayed on three successive days with water containing spores and kept for ten days under a moist bell jar there were eventually found only three leaves with a total of five scab colonies. In those cases where colonies developed they were usually first seen about three weeks after the spores had been put on the leaves. The experiment was also tried of spraying spores on the unfolding leaves of different varieties of apples whose twigs had been cut off and

placed in water under bell-jars but no results were obtained in these cases since the leaves all dropped off by the end of two weeks.

Venturia or Saprophytic Stage.

On Dead Leaves.—After the scab infected leaves fall from the trees in the autumn and lose their green color the subcuticular mycelium slowly changes. The rounded cells become larger (eventually 5—10 μ in diameter) and gradually tinted to a reddish olive color and also give rise to similarly colored mycelial threads that penetrate into the interior of the leaf. In sections made of fallen leaves gathered in October there were seen signs of the formation of perithecial bodies and occasionally threads could be traced connecting these with the subcuticular cells. The perethecia generally originate in the loose part of the leaf a short distance above the lower epidermal cells, and while still young show an outer covering of colored cells and a few inner hyaline ones.

The Venturia stage is thus produced from the mycelium of the scab stage, the dead leaves allowing easy penetration into the interior and offering no hindrance to further development. From the fact that the perithecia most frequently occur on the lower side of leaves and are not found unusually abundant on or near conspicuously scabby spots, it seems quite probable that the less conspicuous scab colonies originating in the fall on the under side of the leaves are largely responsible for the development of this stage.

The relationship of these two forms is well shown by the following data obtained regarding their development.

May. Scab first appears on young apple leaves and fruit and during this month and June obtains its greatest foothold.

July to September. The warm, generally dry, weather is not very favorable for spreading the disease to the leaves, and fruit usually suffers but little from further infection.

September and October. Scab appears to develop somewhat more abundantly especially on the lower surfaces of the leaves, but not necessarily in vigorous fruiting condition.

October and later. On the fallen dead leaves there are signs of the formation of the perithecia of the Venturia stage.

October to April. Perithecia slowly develop as weather conditions prove favorable.

April and May. Perithecia with mature ascospores are now found.

June. Venturia stage disappears.

The Venturia stage was found most abundant the spring of the year apple scab was the worst. After one severe winter it was apparently injured by the cold since many of the perithecia never came to maturity. It was never found on any other leaves than the apple and succeeded best where these were protected by sod, especially where more or less heaped together in fence corners.

The perithecia show on the leaves as small black pustules generally scattered but sometimes congregated in small groups often on greyish spots which may mark the place of the fall scab colony. They frequently occur in the vicinity of the veins. Sometimes they are found on leaves that show no sign of scab to the naked eye. When mature they are more or less loosely imbedded in the leaf tissues and at the time of their disappearance infected leaves often show numerous small holes where they had been imbedded. The writer has never found them upon the old fruit and only once on the twigs and in this case the single large perithecium was probably blown there.

Microscopical Appearance.—From the examination of various specimens the microscopical characters may be given as follows: Perithecia when mature very dark, light scarcely shining through unless crushed and then showing outer wall of dark olive green color, spherical or subspherical, generally 90—150 μ in diameter; reticulations (Fig. 27) not evident until perithecia are crushed, irregularly polygonal, 5—15 μ; ostiolum showing at first as a lighter spot, usually on a broad somewhat beaked projection (Fig. 29 and 30); bristles (Fig. 28) absent or surrounding the projection, six or more in number, easily detached, of same color as perithecium, simple, tapering somewhat from base to apex, usually about 35 μ though varying at least from 25—75 μ in length; asci (Fig. 27; Plate III, Fig. A) numerous, at least when mature without paraphyses intermixed, without very evident stipe, oblong to spatulate, frequently slightly curved, 55—75 μ x 6—12 μ; spores (Fig. 27; Plate III, Fig. B) eight in an ascus, upper single ranked, lower irregularly two ranked, two celled with ratio of length of cells about 2:3, oblong, with upper cell usually slightly wider than lower, light reddish or olive brown, 11—15 μ x 5—7 μ.

Germination of Spores.—Spores when placed in water in Van Tieghem cells germinate rather abundantly within the first twenty-four hours. They become considerably swollen and then send out a germ-thread from one or both cells, but most frequently only from the lower cell. While these threads may originate from any part of the cell they usually come from the free end. They attain a length several times the length of the spore, taper somewhat toward free end and become septate at the base (Plate III, Fig. E).

In apple leaf agar the germination was more vigorous with the production of the curiously enlarged and irregularly knobbed or branched tinted tips (Plate IV, Fig. C) that were also produced in cultures from scab spores. In one culture the mycelium also gave rise to true scab spores (Plate IV, Fig. D).

Artificial Cultures.—Colonies were produced from spores in Petri dish separation cultures like those from scab spores, small, lax, and of slow development. So far as tried the growths on various media were similar to those of the scab stage. The fungus did best on apple corn meal where it produced characteristic threads and spores of scab.

The culture work with this stage was not carried on very extensively because of the difficulty of finding spores in 1899 and because in 1900 much of the time during the season of the fungus was spent working with another fungus supposed to be probably an immature condition of the Venturia. This was finally seen to be Sphærella and was determined by Ellis as *Sphærella pirina*, E. & E. This fungus also is found on the dead leaves, apparently quite common. It occurs most abundantly upon the upper surface and produces more or less grouped perithecia that are smaller and originally not so deeply imbedded in the leaf as those of the Venturia. The mature perithecia also lack the bristles that are usually present with the Venturia and the spores differ in being smaller and hyaline.

Identity.—The apple leaf Venturia has been commonly called *Venturia chlorospora* (Ces.) Karst., which name was also made to include various forms on the fallen leaves of other hosts, such as Salix, etc. Aderhold has recently shown that these forms are distinct, even those occurring on the closely related hosts pear and cherry being different species from that on the apple. For this latter form he has adopted the name *Venturia inæquatis* (Cke.) Ad., using the specific name first applied by Cooke. The latter described this as a new species, *Sphærella inæqualis*, in Seem. Journ. Bot. in 1866, Niessl in 1881, Rabenhorst's Fungi europaei no. 2663, placed this species under the genus Didymosphæria as *D. inæqualis* (Cke.) Nessl. Winter, instead of Aderhold, seems to have been the first to place the species under the genus Venturia as the specimens on apple leaves distributed in 1880 in de Thümen's Mycotheca universalis no. 1544 are called *Venturia inæqualis*, Wint. in litt.

Nomenclature.

Fries was probably the first botanist to give a name to apple scab. About 1819 in Nov. Fl. Suec. he applied the name *Spilocæa Pomi* to the fructigenous form. In his Syst. Myc. in 1829 he also described this species and this is the reference for the name usually given by botanists. On the same page of this latter work he described a fungus on the leaves of apple and pear that to the writer

seems to be the leaf form of scab, though *Spilocæa epiphylla* is never given as one of its synonyms. Persoon in 1822 under the name *Fumago Mali* also described a fungus on the leaves of apple that by some botanists has been questioningly referred to scab. In 1833 Wallroth unquestioningly found the leaf form and named it *Cladosporium dendriticum*. Fuckel in 1869 placed this under the genus Fusicladium and since that time scab has been commonly called *Fusicladium dendriticum* (Wallr.) Fckl. In 1834 Schweinitz described a new species on Newton Pippin apples from this country under the name of *Dothidea pomigena*.* This has been considered by some botanists as probably another name for the fructigenous form of this fungus. The writer was inclined to this view and so recently examined Schweinitz's specimen in the Herbarium of the Philadelphia Academy of Science. While the specimen was in poor condition it was seen that it was not scab, being more like the fly speck fungus in its macroscopic appearance. Schweinitz, however, did list apple scab from this country under the names *Spilocæa fructigena* or *S. Pomi*. He seems to have originated the name *fructigena* though from his reference one would suppose that Fries was authority for it. The specimen in the Schweinitz collection is labeled *Spilocæa Pomi*. In 1851 Bonorden described a scab fungus under the name of *Fusicladium virescens*. There is some doubt whether this is a synonym of the apple or the pear scab. Bonorden gives apple as the host for his fungus but his figures more nearly resemble the scab of the pear, and so some botanists give it as a synonym of this. The last person to give a new name to this fungus was de Thümen who, in 1875, described the form on the fruit as *Napicladium Sorauerí*.

Since it has been clearly shown that scab is merely a stage of a Venturia it must now be named under that genus instead of under Fusicladium. *Venturia inæqualis* (Cke.) Wint., seems an appropriate name, though some botanists would use for the specific name the one first given to any of the stages of the fungus, which in this case is *Pomi*. Another possible objection against the use of the above name is that Cooke's *Sphærella inæqualis* also included the form on the pear, which is now considered a distinct species.

The different names applied to the scab stage, as found by the writer, are as follows:

Spilocæa Pomi, Fr. Nov. Fl. Suec. 5 : 79. 1819.
? *Fumago Mali*, Pers. Myc. Eur. 1 : 9. 1822.

*Sturgis (Am. Rep. Conn. Agr. Exp. Stat. 21:171) thinks that this description applies to what he calls the Sooty Blotch fungus.

? *Spilocæa epiphylla*, Fr. Syst. Myc. 3 : 504. 1829.
Cladosporium dendriticum, Wallr. Fl. Crypt. Germ. 1[2] : 169. 1833.
Spilocæa fructigena, Schw. N. A. F. : 297. 1834.
? *Fusicladium virescens*, Bon. Handb. Allg. Myk. : 80. 1851.
Fusicladium dendriticum, Fckl. Symb. Myc. : 357. 1869.
Napicladium Soraueri, Thüm. Hedw. 14 : 3–4. 1875.
Fusicladium dendriticum f. *Pyri Mali*, Thüm. Myc. uni. no. 1174. 1878.
Fusicladium dendriticum, var. *minor*. Sacc. fungi Ital. *f. 782*. 1881.
Fusicladium dendriticum var. *Soraureri*, Sacc. Syll. Fung. 4 : 346. 1886.
Fusicladium dendriticum forma microsperma, Roum. Fungi sel. exs. no. 5592. 1890.

Exsiccati.

Fusicladium dendriticum (Wallr.) Fckl. has been distributed in a number of different exsiccati of which the following have been examined by the writer and found to be this fungus :

Spilocæa Pomi, Fr. on apple fruit. Scler. Suec. exs. no. 260.
Cladosporium dendriticum, Wallr. on apple leaves. Herb. crypt. belg. no. 695.
Cladosporium dendriticum, Wallr. on *Pyrus Malus*. Klotz. herb. viv. myc, no. 1883.
Cladosporium dendriticum, Wallr. on leaves Pyrus. Klotz. herb. viv. myc. II. no. 766.
Napicladium Soraueri, Thüm. on apple fruit. Thüm. Myc. uni. no. 91.
Napicladium Soraueri, Thüm. on apple fruit. Roum. Fung. sel. Gall. exs. no. 154.
Fusicladium dendriticum forma *microsperma*, on leaves of apple. Roum. Fung. sel. exs. no. 5592.
Fusicladium dendriticum f. *Pyri Mali*, on leaves *Pyrus Malus*. Thüm. Myc. uni. no. 1174.
Fusicladium dendriticum (Wallr.) Fckl. on leaves *Pyrus Malus*. Sey. & Earle Eco. Fungi no. 38.
Fusicladium dendriticum (Wallr.) Fckl. on fruit *Pyrus Iowensis*. Sey. & Earle Eco. Fungi. no. 420.
Fusicladium dendriticum, Wallr. on leaves *Pyrus Malus*. Ell. N. A. F. no. 372b.
Fusicladium dendriticum (Wallr.) on leaves *Pyrus Malus*. Ell. & Ev. Fungi. Col. no. 464.

Fusicladium dendriticum (Wallr.) Fckl. on leaves *Pyrus Malus*. Briosi & Cavara Fung. par. no. 140.

Fusicladium dendriticum (Wallr.) on leaves *Pirus prunifolia*. Rab-Wint-Paz. Fungi eur. no. 3997.

Besides these there were found a number of specimens distributed on Cratægus and Sorbus under various names that have the appearance of this fungus, but which were not included with the above because of lack of knowledge concerning their permanent stage.

Bibliography.

Apple scab has been the subject for much writing on the part of botanists and horticulturists. This is due to its wide distribution and the considerable injury that it causes. Much of this literature relates to experiments for the prevention of its ravages, especially by the use of fungicides. The following references relate to articles and notes that the writer has indexed from his examination of such literature as was at his disposal. No doubt many more references could be added to the list:

Aderhold, R. Die Perithecienform von *Fusicladium dendriticum* (*Venturia chlorospora* f. *Mali*). Ber. Deutsch. Bot. Ges. **12**: 338–342. 1894.
Shows the relationship between *F. dendriticum* on living apple leaves and *V. chlorospora* f. *Mali* the permanent stage on the dead leaves.

Aderhold, R. Litterarische Berichtigung zu dem Aufsatze ueber die Perithecienform von *Fusicladium dendriticum*, Wallr. Ber. Deutsch. Bot. Ges. **13**: 54 - 5. 1895.
Speaks of earlier investigations connecting *Fusicladium dendriticum* with Venturia stage.

Aderhold, R. Die Fusicladien unserer Obstbaume. Landw. Jahrb. **25**: 875 - 914. 1896. [Illustr.] *Ibid.* **29**: 541 - 587. 1900. [Illustr.]
Gives detailed accounts of the scabs of apples, pear and cherry and shows their relation to Venturia stages on dead leaves of these hosts.

Aderhold, R. Revision der species *Venturia chlorospora, inæqualis* und *ditricha* autorum. Hedw. **36**: 81. 1897. [Illustr.]
Describes the different species of Venturia and gives their hyphomycetous stages, placing *Fusicladium dendriticum* under *Venturia inæqualis* (Cooke) Ad.

Alwood, W. B. *Fusicladium dendriticum*. Virg. Agr. Exp. Stat. Bull. 24: 24. 1893.
Mentions this as cause of one of the serious apple diseases in this state.

Andre, Ed. Les Fusicladium et nos Vergers. Rev. Hort. **60**: 246. 1888.
Gives short description of apple scab.

Anon. Apple and Pear Scab. N. Y. Agr. Exp. Stat. Bull. 35: 606-7. 1891.
Describes briefly effect of fungus and recommends preventive treatment by spraying.

Anon. Treating Apple Orchard for Scab. N. Y. Agr. Exp. Stat. Bull. 84 : 19-20, 31-33. 1895.
Recommends time for spraying and notes varieties injured by Bordeaux mixture.

Anon. Apple Scab. Year Book, U. S. Dept. Agr. **1894** : 577. *Ibid.* **1895** : 587. *Ibid.* **1896** : 625. *Ibid.* **1897** : 673.
Gives treatment for prevention of scab.

Arthur, J C. Apple Scab and Leaf Blight. Ann. Rep. N. Y. Agr. Exp. Stat. **3** : 370. 1885.
Gives short note on damage caused by this fungus.

Bailey, L. H. Scab-proof Apples. Gard. & For. **5** : 442. 1892.
States that there is no marketable scab-proof variety,—Baldwin the least susceptible.

Bailey, L. H. The Recent Apple Failures. Corn. Agr. Exp. Stat. Bull. 84 : 58-63, 66-8. 1895. [Illustr.]
Attributes apple scab as chief cause of failures and discusses the fungus and methods of combating it.

Beach, S. A Wood Ashes and Apple Scab. N. Y. Agr. Exp. Stat. Bull. 140 : 665-90. 1897.
Reports experiments of applying wood ashes to the soil as not preventing scab.

Beach, S. A. and **Paddock W.** Apple Scab. Ann. Rep. N. Y. Agr. Exp. Stat. **14** : 345-7. 1896.
Discuss briefly apple scab and prevention by Bordeaux mixture.

Beach, S. A , Lowe, V. H , and **Stewart, F. C.** Scab. N. Y. Agr, Exp. Stat. 170 : 385-7. 1899.
Give short account of life history and methods of prevention.

Berkeley, M J. Why Do Pears and Apples Crack? Gard. Chron. **1855.** 724. 1855.
States that this due to *Spilocæa Pomi*, the fructigenous form of *Helminthosporium Pirorum*, but does not recognize specific difference between the forms on apple and pear.

Bizzozero, G. *Fusicladium dendriticum* var. *minor*, Sacc. Fl. Ven. Crittog. **1** : 510. 1885.
Follows Saccardo in giving form on apple as variety of that on pear.

Blair, J. C. Spraying Apple Trees with special reference to Apple Scab Fungus. Ill. Agr. Exp. Stat. Bull. 54 : 181-204. 1899. [Illustr.]
Gives results of spraying, directions for making fungicide, description of machinery, etc.

Bonorden, H F. *Fusicladium virescens.* Handb Allg. Myk. : 80. *t. 4, f. 94.* 1851.
Describes this as a new genus and species and says in part "Kommt in Garten auf veredelten Apfelbaumen vor." Winter gives this as a synonym of pear scab and Bonorden's figures certainly more nearly resemble that species than the one on the apple.

Brefeld, O. *Venturia ditricha* f. *Piri.* Unter. Gesammt. Mykol heft. 10 : 221. *t. 7, f. 59, 60.* 1891.
Shows similarity of a stage produced from above fungus to the scab of pear and apple.

Briosi and Cavara. *Fusicladium dendriticum* (Wallr.) Fckl. Fung. par. no 140. 1892.
Give illustrations and specimens of this fungus together with a short description.

Burrill, T. J. Notes on Parasitic Fungi. Agr. Rev: 86. 1882.
Gives an account of apple scab and two other fungi.

Burrill, T. J. An Orchard Scourge. Trans. Miss. Vall. Hort. Soc. **1**:202-7. 1883.
Gives an account of apple scab and the damage caused in Illinois.

Burrill, T. J. The Apple Scab Fungus. Trans. Ill. Hort. Soc. **1900**:86-97. 1901.
Writes a popular article on our present knowledge of apple scab.

Butz, G. C. Apple Scab. Penn. Agr. Exp. Stat. Bull. 43:13, 16. 1898.
Treats of apple scab and its prevention by spraying.

Card, F. W. Apple Scab in Nebraska. Gard. & For. **8**:28. 1895.
Thinks little scab found in this state is due to dry weather.

Chester, F. D. The Scab of the Apple and Pear. Del. Agr. Exp. Stat. Bull. 3:6-7. 1888.
Gives short note on above including preventive measures.

Chester, F. D. Experiment in the Treatment of Apple Scab. Del. Agr. Exp. Stat. Bull. 29:18-24. 1895.
Gives favorable results from spraying with Bordeaux mixture.

Chester, F. D. Experiment in the Treatment of Apple Scab. Del. Agr. Exp. Stat. Bull. 34:14-9. 1897. [Illustr.]
Records favorable results from spraying with Bordeaux mixture.

Chester, F. D. Continuation of the Work on the Treatment of Apple Scab. Ann. Rep. Del. Agr. Exp. Stat. **11**:27-30. 1900.
Describes successful spraying experiments with Bordeaux mixture.

Clark, J. W. Spraying for the Codling Moth and Apple Scab. Mo. Agr. Exp. Stat. Bull. 13:6. 1891.
Reports favorable results from spraying with Bordeaux mixture.

Close, C. P. Apple Scab. Utah Agr. Exp. Stat. Bull. 65:67-8. 1900.
Gives note on appearance of scab and remedy.

Cobb, N. A. Apple Scab. Agr. Gaz. N. S. Wales **2**:216, 492. 1891.
Reports this on increase and suggests use of fungicides.

Cobb, N. A. Apple Scab, "Tasmanian Black Spot." Agr. Gaz. N. S. Wales **3**:276-8. 1892. [Illustr.]
Gives short botanical account of the fungus and of the best fungicides for prevention.

Collier, P. Apple Scab and Pear Scab. Ann. Rep. N. Y. Agr. Exp. Stat. **9**:337-9. 1891.
Describes effect of this on leaves and fruit and suggests preventives.

Comes, O. *Fusicladium dentriticum*, Fck. Critt. Agr.:394. 1891.
Gives short account of this fungus.

Cooke, M. C. *Sphærella inæqualis*, Cke. Seem. Journ. Bot. **4**:248-9, 1866. [Illustr.]
Describes this as a new species on various hosts of the Pomaceæ.

Cooke, M. C. *Sphærella inæqualis*, Cke. Handb. Brit. Fungi:916. 1871.
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Cooke, M. C. *Spilocæa pomi*, Fr. Grev. 2:64. 1873.
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Lists it as occurring in the U. S. on apple leaves and fruit.

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Corbett, L. C. Apple Scab. W. Virg. Agr. Exp. Stat. Bull. 66:204-6. 1900. [Illustr.]
Gives characters of apple scab and best preventive treatment.

Corbett, L. C The Value of Spraying. W. Virg. Agr. Exp. Stat. Bull. 70:354-5. 1900. [Illustr.]
Gives results of experiments showing time best to spray for scab.

Costantin, J. Fusicladium. Les Mucedinees Simples: 69-71. 1888.
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Curtis, M A. *Spilocæa Pomi*, Fr. Curtis' Cat. Plants N. Car: 121. 1867.
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Detmers, Freda. Apple Scab. Ohio Agr. Exp. Stat. 49:187-92. 1891. [Illustr.]
Gives short description of apple scab fungus and its injury.

Ellis, J. B. *Dothidea pomigena*, Schw. N. A. Pyr: 605. 1892.
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Eriksson, J. Der Schorf der Obstbaume. Bot. Centr. 26:345-7. 1886.
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Fairchild, D. G. Apple Scab. Div. Veg. Path. U. S. Dep. Agr. Bull. 6:43-4. 1894.
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Flagg, C. O. The Use of Fungicides in the Treatment of the Apple Scab. R. I. Agr. Exp. Stat. Bull. 15:21-2. 1892.
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***Fries, E.** *Spilocæa Pomi*, Fr. Nov. Fl. Suec. **5**: 79. 1819.
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Fries, E. Spilocæa. Syst. Orb. Veg. **1**: 198. 1825.
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Fries, E. *Spilocæa Pomi*, Fr. Syst. Myc. **3**: 504. 1829.
Describes the form of apple scab found on the fruit.

Fries, E. *Spilocæa epiphylla*, Fr. Syst. Myc. **3**: 504. 1829.
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Galloway, B. T. Notes on the Fungus of Apple Scab. Mich. Agr. Exp. Stat. Bull. 59: 28-9. 1890. [Illustr.]
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Gives description of fungus and discusses different fungicides.

Garman, H. Apple Scab. Ky. Agr. Exp. Stat. Bull. 44: 25-6. 1893.
Notes favorable results from spraying with Bordeaux mixture.

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Goff, E. S. An Experiment for the Prevention of Apple Scab. Ann. Rep. N. Y. Agr. Exp. Stat. **4**: 260. 1886.

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Goff, E. S. Treatment of Apple Scab. Journ. Myc. **6**: 19-21. 1890.
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Goff, E. S. Report on the Treatment of Apple Scab. Sec. Veg. Path. U. S. Dep. Agr. Bull. 11: 22-8. 1890.
Gives results of spraying with different fungicides of which amm. carb. of copper proved most effective.

Goff, E. S. Prevention of Apple Scab, *Fusicladium dendriticum*, Fckl. The Prairie Farmer **62**: 246. 1890.
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Goff, E. S. Prevention of Apple Scab. Wisc. Agr Exp. Stat. Bull. 23: 1-11. 1890. [Illustr.]
Gives description of scab and results of spraying experiments carried on under direction of U. S. Dep. Agr., recommending amm. sol. cop. carbonate.

Goff, E. S. Experiment in the Treatment of Apple Scab. Journ. Myc **7**: 17-22. 1891.
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Goff, E. S. Experimental Treatment for Apple Scab. Ann. Rep. Wisc. Agr. Exp. Stat. **9**: 264, 270. 1893. [Illustr.]
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Green, W. J. Spraying to Prevent Apple Scab. Ohio Agr. Exp. Stat. **4**: 193-212. 1891. [Illustr.]

Reports favorable results from spraying with Bordeaux mixture (4 lb. cop. sulf., 4 lb. lime, 50 gal. water).

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Halsted, B. D. *Fusicladium dendriticum.* Ann. Rep. N. J. Agr. Exp. Stat. **15** : 324. 1895.
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Harvey, F. L. Apple Scab or Black Spot. Ann. Rep. Me. Agr. Exp. Stat. **1888**[2] : 149-51. 1889.
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Harvey, F. L. Apple Scab. Ann. Rep. Me. Agr. Exp. Stat. **1889** : 182-4. 1890. [Illustr.]
Gives notes on the spraying experiments conducted by U. S. Dep. Agr.

Hatch, A. L. Experiments in Treating Apple Scab. Journ. Myc. **7** : 26. 1891.
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Henderson, L. F. Apple Scab in the Potlatch. Idaho Agr. Exp. Stat. Bull. 20 : 79-95. 1899.
Reports favorable results from the use of Bordeaux mixture.

Hoffmann, H. *Cladosporium dendriticum.* Index Fung : 37. 1863.
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Hoskins, T. H. Orchard Spraying. Gard. & For. **5** : 371. 1892.
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Jones, L. R. The Prevention of Apple and Pear Scab by Spraying. Ann. Rep. Verm. Agr. Exp. Stat. **5** : 132-3. 1892.
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Jones, L. R. Apple and Pear Scab. Verm. Agr. Exp. Stat. Bull. 28 : 30-4. 1892.
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Jones, L. R. Apple and Pear Scab. Verm. Agr. Exp. Stat. Bull. 44 : 83-93. 1894. [Illustr.]
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Jones, L. R, and Orton, W. A. Spraying for the Prevention of Apple Scab in 1897. Ann. Rep. Verm. Agr. Exp. Stat. **11** : 195-8. 1898. [Illustr.]
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Keffer, C. A. Spraying Apple Trees. Mo. Agr. Exp. Stat. Bull. 27 : 1 - 24. 1894.
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Kinney, L. F. The Scab of Apple and Pear. Ann. Rep. R. I. Agr. Exp. Stat. 7 : 185 - 7. 1895. [Illustr.]
Gives brief report on nature of scab.

Lamson, H. H. Spraying against Pear and Apple Scab. Ann. Rep. N. H. Coll. Agr. 20 : 217 - 8, 238 - 9. 1892.
Gives short description of scab and reports favorable results from spraying with Bordeaux mixture and amm. sol. cop. carbonate.

Lamson, H. H. Some Fungus Diseases of Plants and Their Treatment. N. H. Agr. Exp. Stat. Bull. 9 : 7 - 11. 1894. [Illustr.]
Describes scab and gives favorable results from spraying with Bordeaux mixture.

Lamson, H. H. Spraying experiments in 1894. N. H. Agr. Exp. Stat. Bull. 27 : 5 - 7. 1895.
Reports favorable results from use of Bordeaux mixture

Lindau, G. *Venturia chlorospora* (Ces.) Karst. Die Nat. Pflanzenf. 1 : 431. 1897.
Mentions *Fusicladium dendriticum*, Wallr. as stage of above fungus.

Link, H. F. *Spilocœa Pomi.* Linn. Sp. Plant. 6[2] : 86. 1825.
Gives a description of the fructigenous form of the apple scab.

Lodeman, E. G. Spraying Apple Orchards in a wet Season. Corn. Agr. Exp. Stat. Bull. 48 : 265 - 98. 1892. [Illustr.]
Gives results of spraying with Bordeaux mixture, a table of varieties most and least likely to scab, and the chemistry of Bordeaux mixture.

Lodeman, E. G. The Profits of Spraying Apple Orchards. Corn. Agr. Exp. Stat. Bull. 60 : 257 - 79. 1893.
Gives results of spraying experiments chiefly with fungicides against apple scab.

Lodeman, E. G. The Spraying of Orchards. Corn. Agr. Exp. Stat. Bull. 86 : 105 - 25. 1895.
Gives suggestions and results of spraying apples chiefly against scab.

Macoun, W. T. Black Spot Fungus or Scab. Dep. Agr. Cent. Exp. Farm, Ottawa, Can. Bull. 37 ; 67 - 8. 1901.
Notes this fungus as being very troublesome during recent years, etc.

Massee, G. Apple Scab. A Text Book of Plant Diseases : 302 - 4, 435. 1899 [Illustr.]
Gives a short botanical description of this fungus together with preventive measures.

Maynard, S. T. Fungicides and Insecticides on the Apple, Pear, and Plum. Mass. Hatch. Agr. Exp. Stat. Bull. 11 : 12 - 6. 1891.
Reports various spraying experiments which so far as preventing apple scab were not very successful.

McCarthy, G. Apple Scab. N. C. Agr. Exp. Stat. Bull. 76 : 15. 1891.
Gives short note on scab and means for prevention.

McCarthy, G. Apple Scab. N. C. Agr. Exp. Stat. Bull. 92 : 87 - 8. 1893.
Gives general information concerning scab and list of varieties most and least liable to attack.

Munson, W. M Spraying Experiments. Ann. Rep. Me. Agr. Exp. Stat. **1891**: 110-8. 1892. [Illustr.]
Gives account of scab and results of favorable spraying experiments with eau celeste and amm. sol. cop. carbonate.

Munson, W. M. Spraying Experiments. Ann. Rep. Me. Agr. Exp. Stat. **1892**: 92-8. 1893.
Reports favorable results from spraying with eau celeste against scab.

Munson, W. M. Notes on Spraying Experiments. Ann. Rep. Me. Agr. Exp. Stat. **1893**[2]: 124-8. 1894. [Illustr.]
Gives favorable results from spraying with Bordeaux mixture against scab.

Niessl, G. V. *Didymosphæria inæqualis* (Cke.) Nssl. Rab. Fung. eur. no. 2663. 1881.
Changes to above name from *Sphærella inæqualis.* Cke.

Niessl, G. V. Bemerkung ueber *Venturia inæqualis,* Cke. und verwandte Formen. Hedw. Beibl. **37**: 1-2. 1898.
Criticises Aderhold for placing above species under genus Venturia merely because of presence of bristles around ostiolum.

Pammel, L. H. Apple Scab and Leaf Blight. Prairie Farmer. **57**: 746. 1885. [Illustr.]
Gives abstract of Trelease's article.

Pammel, L. H. Apple Scab. Ia. Agr. Exp. Stat. Bull. 13: 48-9. 1891. [Illustr.]
Gives cop. carbonate as fungicide for this disease.

Peck, C. H. *Spilocæa Pomi,* Fr. N. Y. St. Mus. Nat. Hist. **23**: 55. 1872.
Reports scab common on apples in N. Y. in 1869.

Peck, C. H. *Fusicladium dendriticum,* Wallr. N. Y. St. Mus. Nat. Hist. **34**: 32-3. 1883.
Gives short account of above including with it forms on pear, etc.

Persoon, C. H. *Fumago Mali.* Myc. Eur. **1**: 9. 1822.
Gives brief description of above fungus which may possibly be the apple scab

Piper, C. V. Apple Scab. Wash. Agr. Exp. Stat. Bull. 8: 138. 1893.
Writes briefly about apple scab and its prevention by spraying.

Powell, G. H. The Apple Scab. Gard. and For. **7**: 297. 1894.
Gives list of varieties most and least affected by scab as determined at Corn. Exp. Stat.

Roumeguere, C. *Fusicladium dendriticum* forma *microsperma.* Roum. Fungi. sel. exs. n. 5592. 1890.
Describes briefly this new form of which a specimen is given.

Saccardo, P. A. *Fusicladium dendriticum* (Wallr.) Fckl. var. *minor* Sacc. Fung. Ital. *f. 782.* 1881.
Gives form on apple as variety of that on pear.

Saccardo, P. A. *Fusicladium dendriticum* (Wallr.) Fckl. Syll. Fung. **4**: 345. 1886.
Gives botanical description of above species.

Saccardo, P. A. *Fusicladium dendriticum* (Wallr.) Fckl. var. *Soraureri* (Thuem.) Sacc. Syll. Fung. **4**: 346. 1886.
Reduces Thuemen's *Napicladium Soraueri* to variety of apple scab.

Schroeter, J. *Fusicladium dendriticum,* (Wallr.) Kryp. Fl. Schl. **3**[2]: 352. 1894.
Describes scab on apple and pear as a conidial stage of *Venturia chlorospora.*

Schweinitz, L. D. de *Spilocæa fructigena* aut *Pomi*, Lk. Syn. F. N. A.: 297. 1834.
Reports above not rare on Newton Pippin; seems to have originated the specific name "*fructigena.*"

Scribner, F. Lamson. Fungous Diseases of Plants. Ann. Rep. U. S. Dept. Agr. **1885**: 81.
Suggests raking and burning of leaves as of possible benefit in preventing apple scab.

Scribner, F. Lamson. Apple Scab. Ann. Rep. U. S. Dep. Agr. **1887**: 341-7. 1888. [Illustr.]
Gives a botanical account of scab, also gives literature and recommends winter treatment with iron sulphate and early spring spraying with Bordeaux mixture.

Scribner F. Lamson, Apple Scab. Tenn. Agr. Exp. Stat. Special Bull. C: 6 1890.
Recommends certain fungicides.

Scribner, F. Lamson. Apple Scab. Fungus Diseases of the Grape and Other Plants: 90-6. 1890. [Illustr.]
Gives short botanical account of the fungus and methods for combating it.

***Scribner, F. Lamson.** Apple Scab and its Treatment. Orch. & Gard. **12**: 113. 1890.
Writes a general article on above subject.

Secretan, L. *Spilocæa pomi.* Myc. Suisse: 594. 1833.
Questions whether Fries' specimen is really distinct from Epochnum.

Selby, A. D. Apple Scab. Ohio Agr. Exp. Stat. Bull. 79: 129-32. 1897. [Illustr.]
Gives short description of apple scab and assigns it as the cause of the dropping of very young apples.

Selby, A. D. Apple Scab. Ohio Agr. Exp. Stat. Bull. 111: 95-115. 1899.
Gives results of various spraying experiments carried on at different times by persons in Ohio.

Smith, E. F. Apple Scab. Journ. Myc. **7**: 373-4. 1894.
Speaks of 1892 as unusually bad year for scab in western N. Y. and southwestern Mich. because of wet spring.

Sorauer, P. Ueber die Entstehung der Rostflecken auf den Fruchten der Kernobstes, *Vers. deutsch. Naturf. u. Aerzte. **1874**: 84-5. [Bot. Zeit: 50-1. 1875.]
Gives botanical account of apple scab on leaves and fruit.

Sorauer, P. Die Entstehung der Rostflecken, auf Aepfeln und Birnen. Monatsschrift Ver. Beford. Gart. Konigl. Preuss. Staaten **18**: 5-15. 1875. [Illustr.]
Gives a description of scabs of apple, pear, etc.

Sorauer, P. *Fusicladium dendriticum.* Die Obstbaumkrankheiten: 100-3. 1882.
Gives account of the gross and microscopical appearance of scab on leaves and fruit.

Sorauer, P. Die Rostflecke der Aepfel und Birnen. Handbuch Pflanzenkrankheiten: 392. 1886.
Describes apple scab briefly.

Sorauer, P. *Fusicladium dendriticum.* Die Schaden Kulturpflanzen : 224. 1888.
Gives short note on this fungus.

Sprague, C. J. *Spilocæa fructigena*, Schw. Proc. Soc. Nat. Hist. Bost. 5 : 329. 1856.
Lists this from New England but does not give host.

Stewart, F. C and **Blodgett, F. H.** Scab. N. Y. Agr. Exp. Stat. 167 : 283. 1899.
Note occurence on twigs of Lady apple.

Stinson, J. T. Apple Scab, etc. Ark. Agr. Exp. Stat. Bull. 21 : 57 - 8. 1892.
Gives directions for spraying with Bordeaux mixture.

Stinson, J. T. Apple Scab. Ark. Agr. Exp. Stat. Bull. 26 : 23 - 33., 37 - 44. 1894.
Gives favorable results from spraying with Bordeaux mixture and notes on damage caused by scab over the state.

Stinson, J. T. Spraying Experiments. Ark. Agr. Exp. Stat. Bull. 39 : 20 - 1. 1896.
Notes that spraying experiments were not profitable because of the lack of scab that year.

Streinz, W. M. Nomenclator fungorum : 187, 280, 308.
Gives *Fumago mali* Pers. and *Helminthosporium pyrorum* Tib. as synonyms of *Cladosporium dendriticum*, Wallr.

Sturgis, W. C. Scab. Conn. Agr. Exp. Stat. Bull. 111 : 3 - 4. 1892.
Describes briefly scab and its prevention by spraying.

Sturgis, W. C. Scab. Conn. Agr. Exp. Stat. Bull. 115 : 3 - 4. 1893.
Gives short note on apple scab.

Sturgis, W. C. Spraying for Scab of Apples and Pear. Ann. Rep. Conn. Agr. Exp. Stat. **17** : 72. 1893.
Gives results of spraying experiments including winter and summer treatments.

Sturgis, W. C. *Fusicladium dendriticum* (Wallr. Fckl) Ann. Rep. Conn. Agr. Exp. Stat. **1900** : 258. 1900.
Gives a few references to literature.

Taft, L. R. Report on Experiments with Remedies for the Apple Scab. Sec. Veg. Path. U. S. Dep. Agr. 11 : 30 - 8. 1890.
Gives experiments of spraying with different fungicides of which modified eau celeste and amm. cop. carbonate gave best results.

Taft, L. R. Report on Experiments made in 1889 in the Treatment of Apple Scab in Michigan. Mich. Agr. Exp. Stat. Bull. 59 : 30 - 42. 1890.
Obtained best results from use of modified eau celeste.

Taft, L. R. Apple Scab. Mich. Agr. Exp. Stat. Bull. 83 : 12 - 4. 1892. [Illustr.]
Presents a short description of the fungus with recommendations for spraying.

Taft, L. R. and **Davis, G. C.** Apple Scab. Mich. Agr. Exp. Stat. Bull. 121 : 19 - 21. 1895. [Illustr.]
Write briefly about scab and recommend use of Bordeaux mixture.

Thuemen, F. v. Napicladium, eine neue Hyphomyceten-Gattung. Hedw. **14** : 3 - 4. 1875.
Describes scab on apple fruit as a new genus.

Thuemen, F. v. *Napicladium Sorauери*, Thuem. Myc. Uni. no. 91. 1875.
Gives specimen and description of his new genus.

Thuemen, F. v. Ueber einige besonders beachtenswerte durch parasitische Pilze hervorgerufene Krankheiten der Apfelbaumblatten. Zeit. Pflanzk. 1 : 167. 1891.

Discusses apple scab and gives *F. dendriticum* var. *Soraueri* and *Napicladium Soraueri* as synonyms.

Tillinghast, J. A. and **Adams, G. E.** Apple Scab. R. I. Agr. Exp. Stat. Bull. 52 : 20 - 1. 1899.

Describe appearance of apple scab and suggest remedy.

Trelease, W. The Apple Scab and Leaf Blight. Ann. Rep. Wisc. Agr. Exp. Stat. 1 : 45 - 56. 1884. [Illustr.]

Gives extended account of scab, varieties attacked, and recommends raking together and burning leaves.

Trelease W. *Fusicladium dendriticum* (Wallr.) Prel. List. Par. Fungi. Wis : 15. 1884.

Lists this as very destructive and on following hosts, *Pyrus Malus, P. coronaria, P. prunifolia.*

Wallroth, F. G. *Cladosporium dendriticum.* Fl. Crypt. Germ. 1^2 : 169. 1833.

Describes this as a new species on apple with questioning reference to identity with Persoon's *Fumago Mali.*

Weed, C. M. Apple Scab. Ohio Agr. Exp. Stat. 2^7 : 188. 1889. (Illustr.)

Reports injury to fruit from spraying with Bordeaux mixture.

Whitten, J. C. The Apple Scab. Mo. Agr. Exp. Stat. Bull. 31 : 3, 6 - 7, 11 - 16. 1895.

Reports favorable results from spraying with Bordeaux mixture.

Williams, T. A. Apple Scab. S. D. Agr. Exp. Stat. Bull. 35 : 79. 1893.

Gives short note on this subject.

Winter, G. Ueber *Napicladium Soraueri,* Thuem. Hedw. **14** : 35 - 6. 1875.

Shows that above fungus is not distinct from *Fusicladium dendriticum* (Wallr.)

Winter, G. *Venturia inæqualis,* Wint. Thuem. Myc. uni. no. 1544. 1880.

Gives this name for first time to specimens on apple leaves.

Explanation of Illustrations.

Fig. 1. Neglected orchard in which scab abounds.

Fig. 2. Sample twig from above orchard showing presence of scab on leaves and fruit.

Fig. 3. Orchard in which scab is kept in check by proper spraying, pruning and cultivating.

Fig. 4. Apple leaves showing scab colonies on upper and lower surfaces.

Fig. 5. Apples showing scabby spots.

Fig. 6–11. Transverse sections of apple leaves infected with scab, showing subcuticular mycelium, development of spores and the lengthening of conidiophores with advance of season; a, parenchymatous cells of leaf; b, epidermal cells of leaf; c, cuticle of epidermis; d, subcuticular mycelium of scab; e, conidiophores of scab; f, scab spores. Fig. 6 shows scab on lower surface of leaf gathered May 3; fig. 7, on upper surface of leaf gathered May 27; fig. 8-9, same date as fig. 7, but spores further developed; fig. 10, on upper surface of leaf gathered June 23; fig. 11, on lower surface of leaf gathered October 1.

Fig. 12–15. Sections through scab colonies on apples; a, parenchymatous cells; b, injured parenchymatous cells forming sort of corky layer; c, cuticle; d, subcuticular mycelium; e, conidiophores; f, spores. Fig. 12 shows scab on fruit gathered June 1; fig. 13, 14, gathered June 23; fig. 15, stored over winter.

Fig. 16. Spores (a) and conidiophores (b) of scab scraped from apple leaf.

Fig. 17. Germinating scab spore (a) showing mycelium developed in a culture of new apple leaf agar.

Fig. 18. Mycelium developed from scab spores, showing granular contents, septa and manner of branching.

Fig. 19. Same as 18 but showing reticular character of protoplasmic contents often seen in young threads or ends of old ones.

Fig. 20. Mycelium with loose spores and large circular swellings in threads probably due to violent osmotic action. Culture impure.

Fig. 21–26. Artificial cultures of scab grown on various media in test tubes, (a) being check test tubes containing no growths. Fig. 21, slight growths on old apple leaves on moist cotton; fig. 22, on beef broth agar; fig. 23, on old apple leaf agar; fig. 24, in beef broth; fig. 25, in gelatin; fig. 26, on beef broth corn meal in which it most nearly approaches its condition in nature.

Fig. 27. Crushed perithecium of *Venturia inæqualis*, showing (a) reticulated walls of perithecium, (b) asco-spores, (c) asci, c′ being an empty ascus.

Fig. 28. Transverse section through old apple leaf of previous year, gathered May 28, and the embedded perithecium of *Venturia inæqualis*, showing latter cut through at side near projecting neck with its characteristic bristles (d).

Fig. 29. Same as Fig. 28 but showing a few of the spores still inside the asci.

Fig. 30. Same as Fig. 28 but section through center of perithecium, spores more or less shrunken.

Fig. 31. A group of swollen germinating spores of *Venturia inæqualis* producing granular, septate threads similar to those from scab spores.

Fig. 32. Same as Fig. 31, but mycelial threads having reticular protoplasm.

Fig. 33. Sterile mycelial threads of Venturia grown on new apple leaf agar.

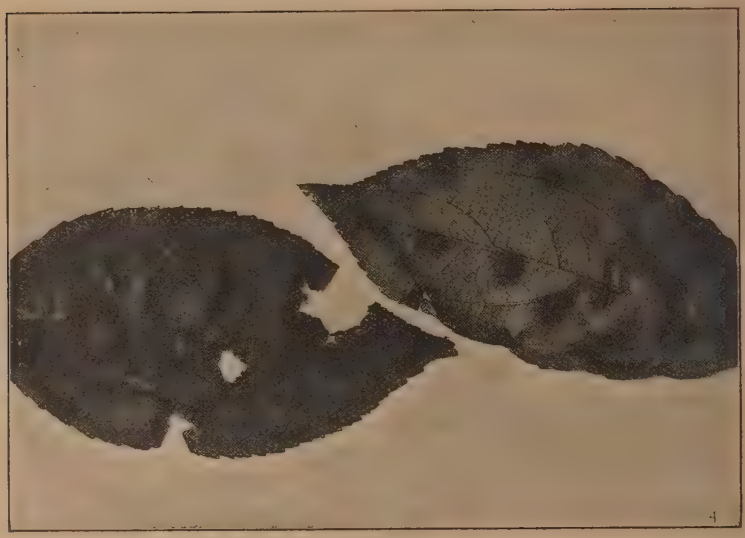
Fig. 34. Fertile mycelial threads of Venturia grown on new apple leaf, corn meal, (a) being one of the scab spores produced.

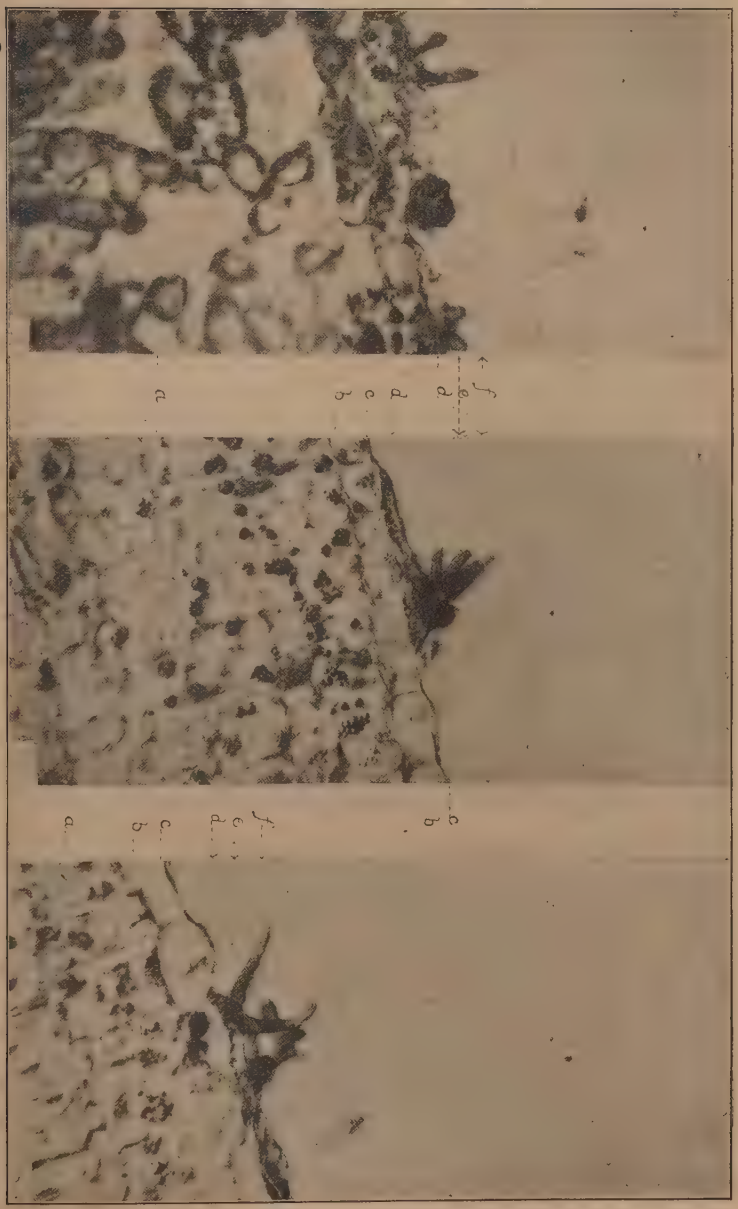
Plate I. Germination and spore production of *Fusicladium dendriticum*: a, spores; b, germ-threads; c, mycelium. Fig. A, germination of spores after 16 hours in water, showing character of young germ-threads and manner of emerging from spores. Fig. B, sterile mycelium of scab third day after transfer to beef broth, showing resulting spore production. Fig. C, same as fig. B, but cultures 24 hours older and spores disappearing through germination. Fig. D, drop culture six days old of spores in apple leaf broth, showing manner in which spores are formed and crowded off by later ones; a′ one of the original spores.

Plate II. Peculiar development of mycelial threads of *Fusicladium dendriticum* in various media under different conditions. Fig. A. peculiarly knobbed and enlarged tinted branches frequently developed on threads in cell cultures. Fig. B, sterile threads grown in apple leaf agar; a, young scarcely tinted threads; b, older, larger and deeper tinted threads; c, peculiar swelling frequently found in threads. Fig. C, peculiar knobbed threads (a) as in Fig. A, sending out more slender, hyaline threads (b). Fig. D, growth of scab mycelium (a) inside of cotton hair (b) showing rounded segments quite like the subcuticular mycelium. Fig. E, mycelium several months old grown on apple leaf agar, showing condensed spore-like condition of thread's contents. Fig. F, a dried out culture on young apple kept over winter, showing same spore-like bodies as in Fig. E.

Plate III. *Venturia inæqualis* from old apple leaves. Fig. A, spores (a) in asci (b) b′ being a ruptured ascus with spores partially escaped. Fig. B, loose spores. Fig. C, perithecium which had been placed in apple leaf broth 15 hours, showing penetration of the enclosed germinating spores. Fig. D, germination of spores after 15 hours in apple leaf broth; a, spore not yet swollen; b, swollen germinating spore; c, swollen spores germinating inside of ascus. Fig. C and D less highly magnified. Fig. E germination of spores within 24 hours after placing in water; a spore; b, germ-thread.

Plate IV. *Venturia inæqualis*. Fig. A, germination of spores after 15 hours in apple leaf broth; a, spores; b, germ-threads. Fig. B, germination of spores after two days in beef broth, showing peculiar knobbed and enlarged ends. Figs. A and B less highly magnified. Fig. C, similar to Fig. B but older culture a′ showing (a) two hours later. Fig. D, mycelium (a) forming true scab spores (b), b′ being spore which germinated after its formation in the new apple leaf broth.

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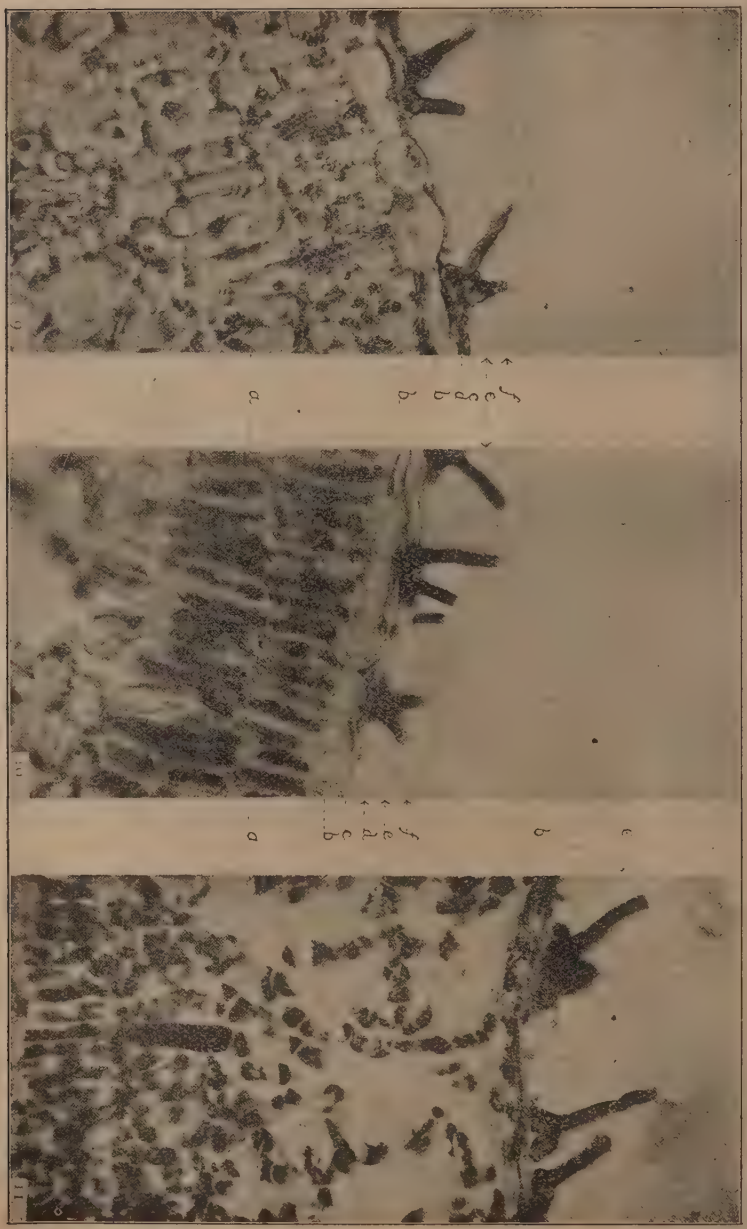

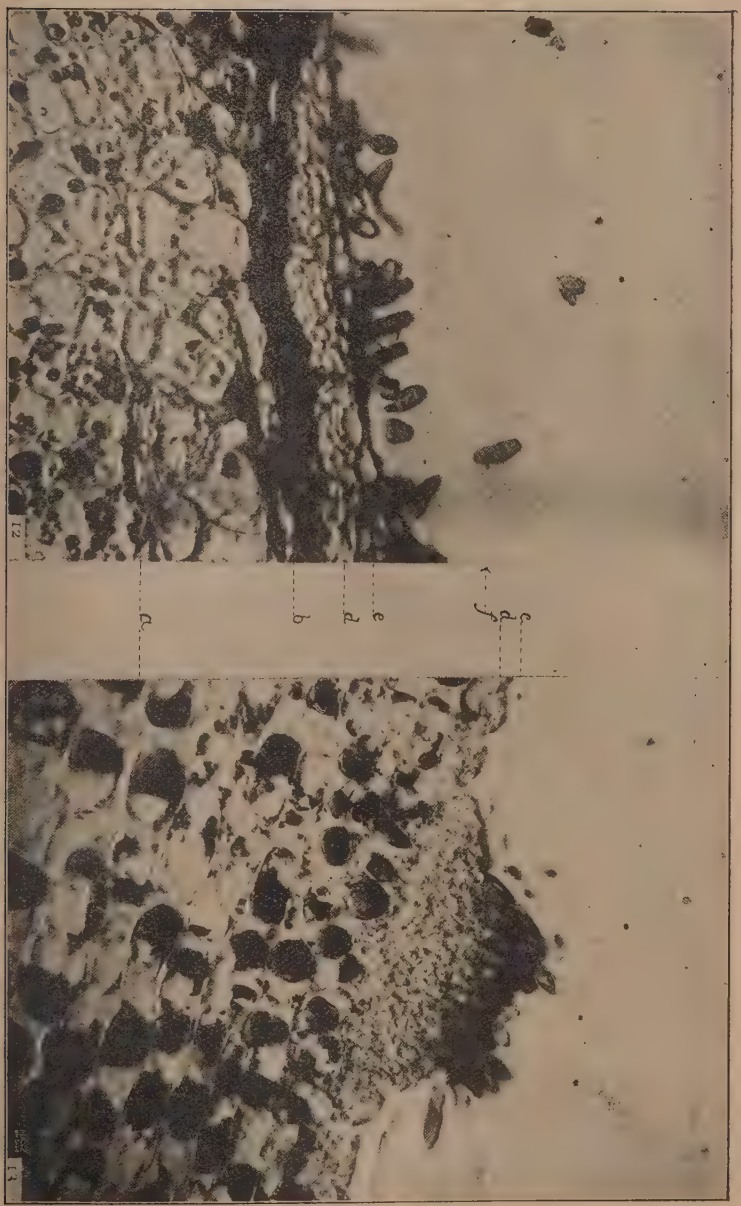
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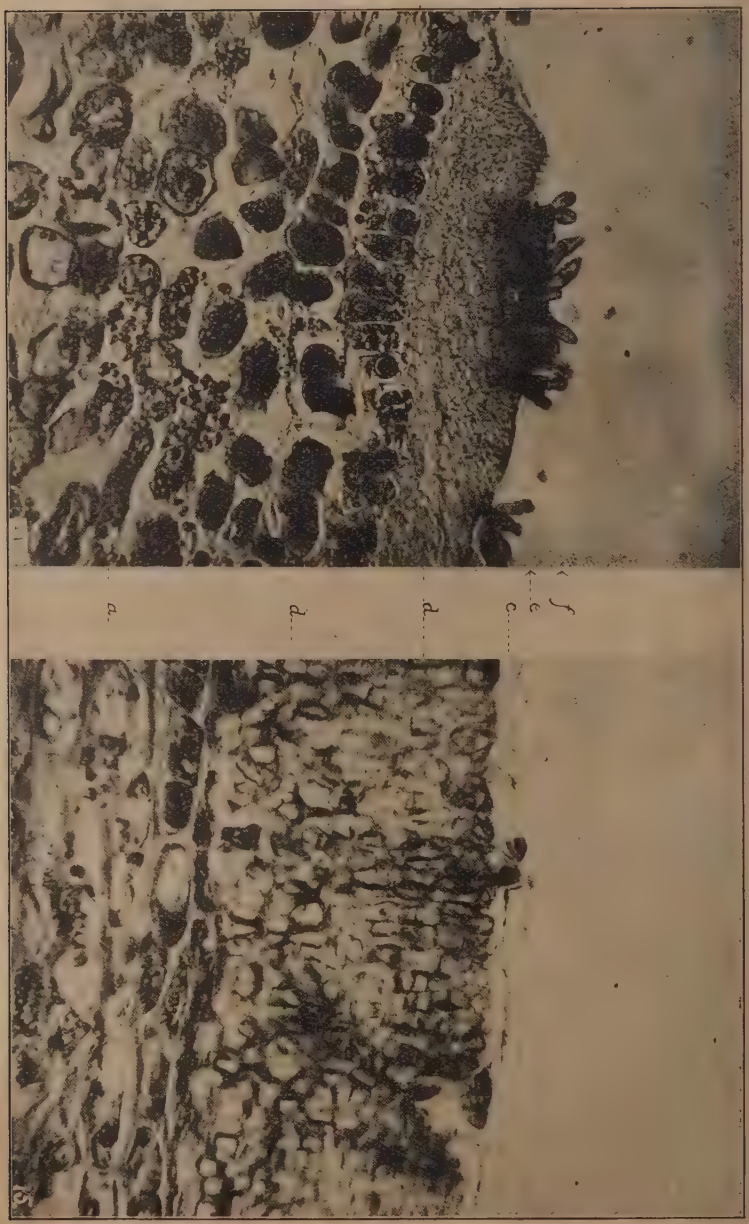
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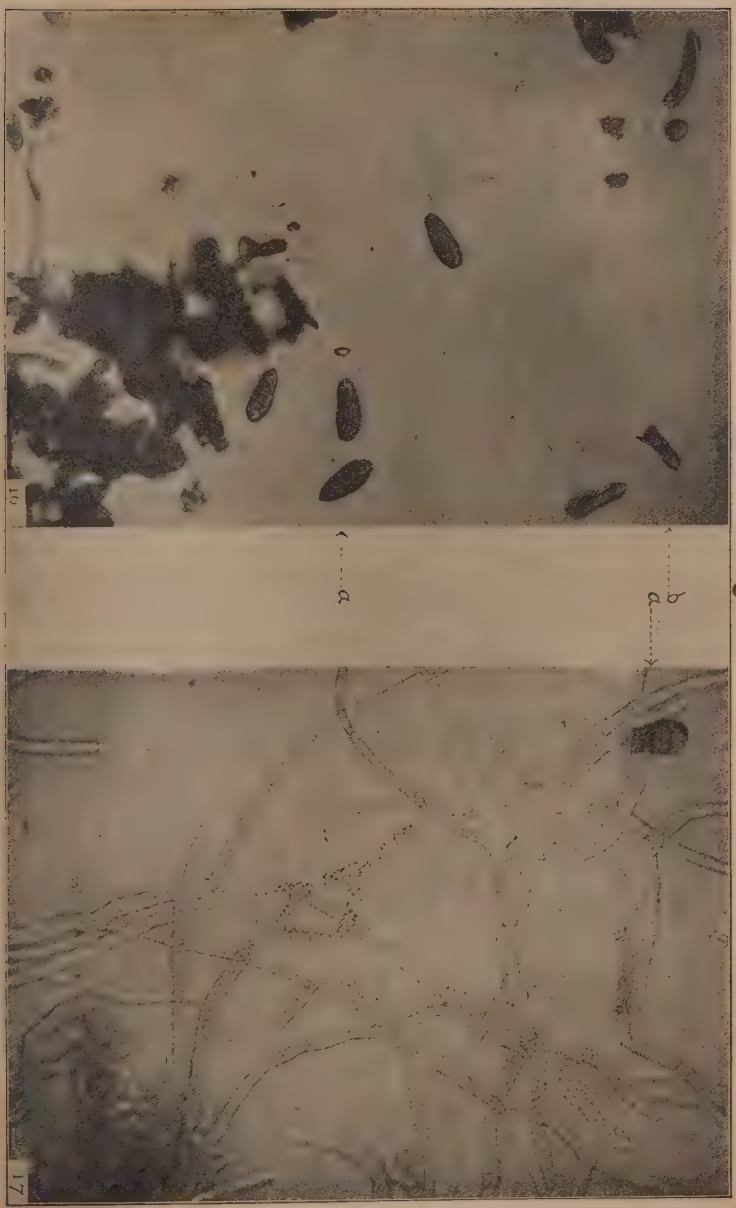
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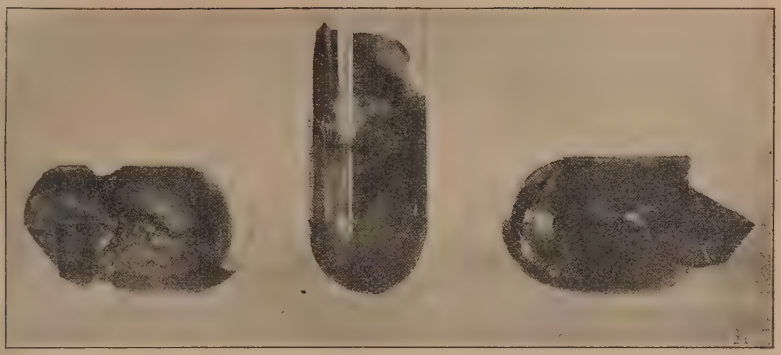

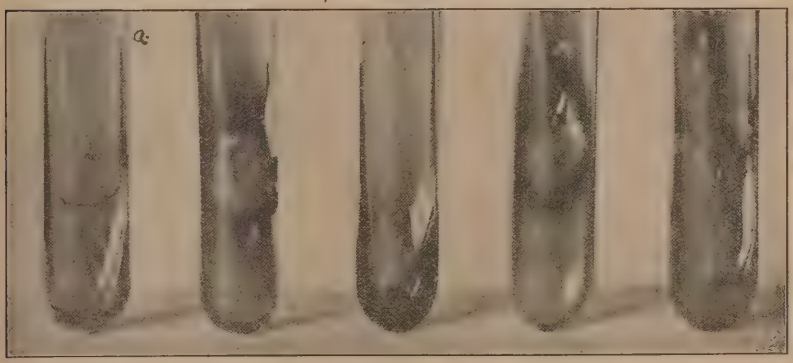
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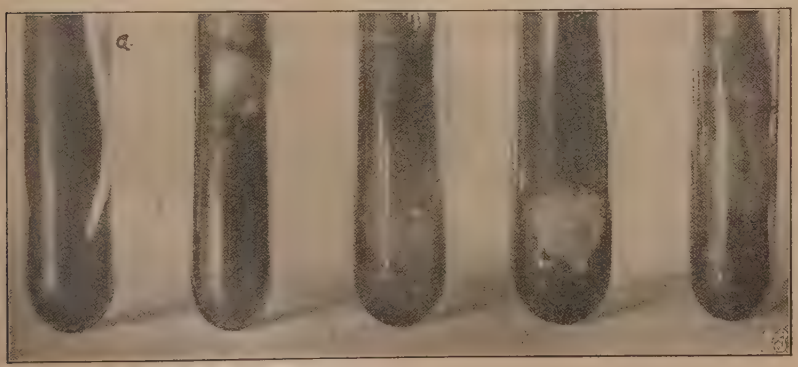
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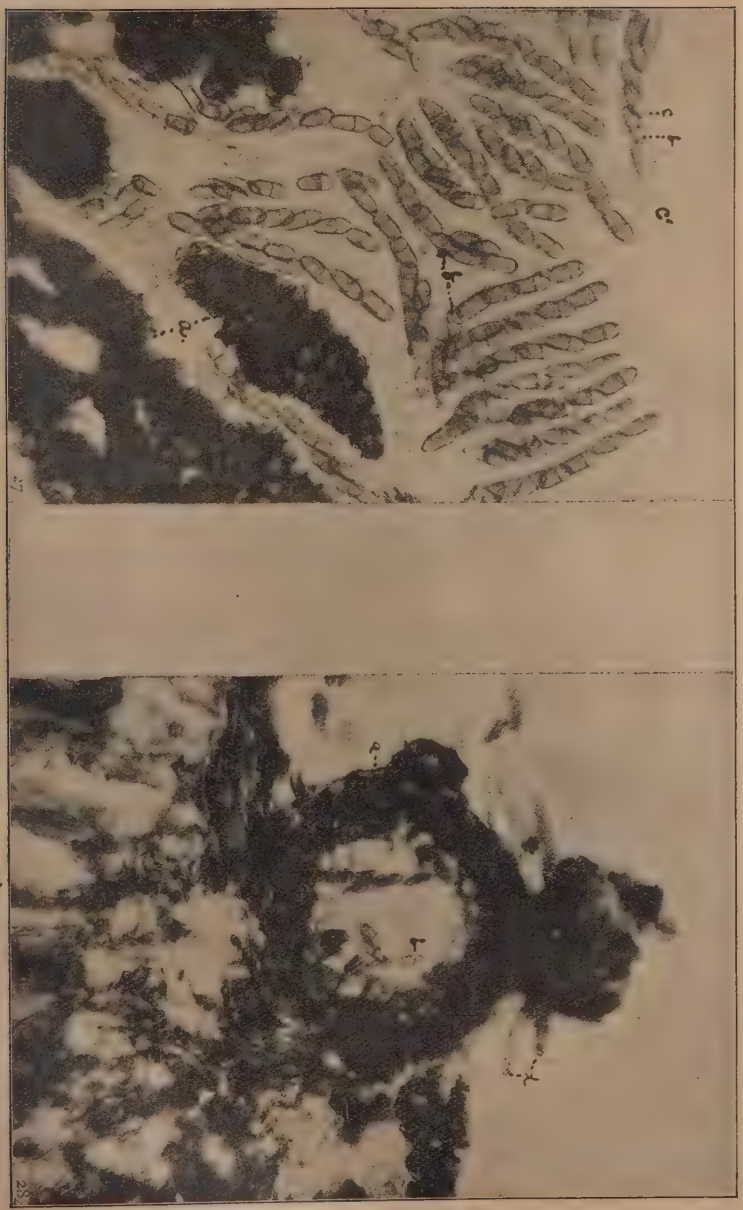
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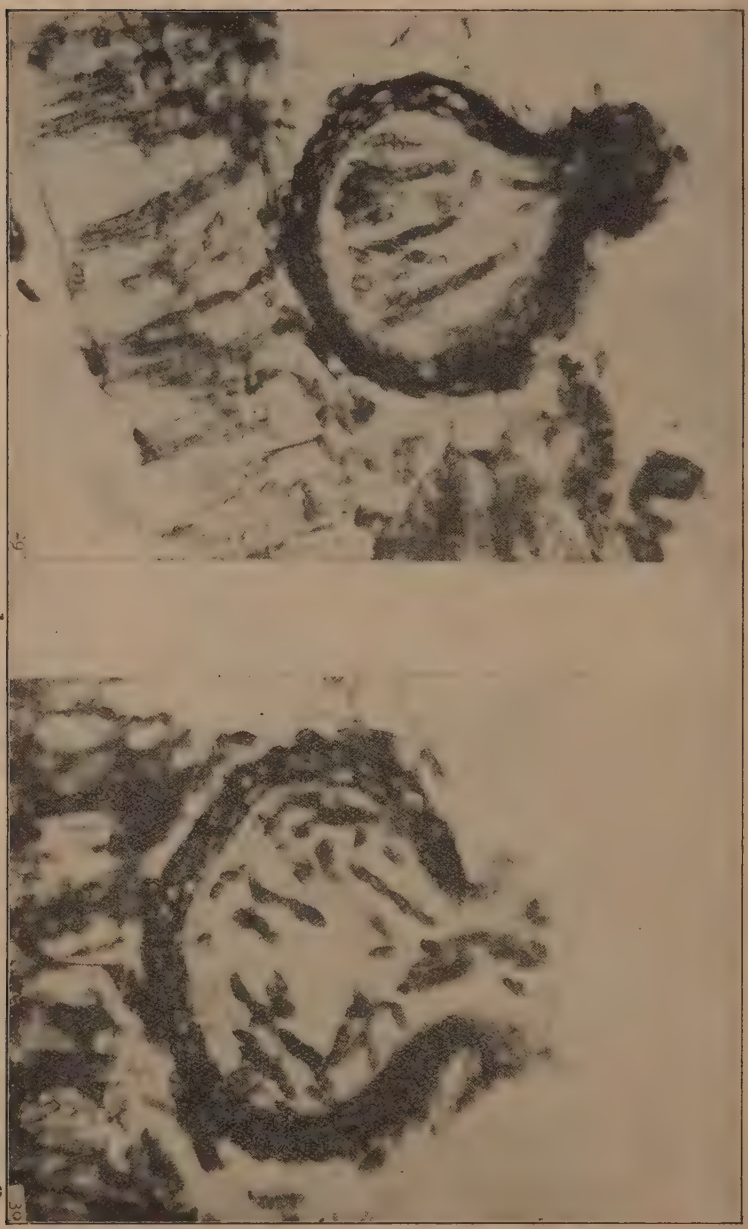

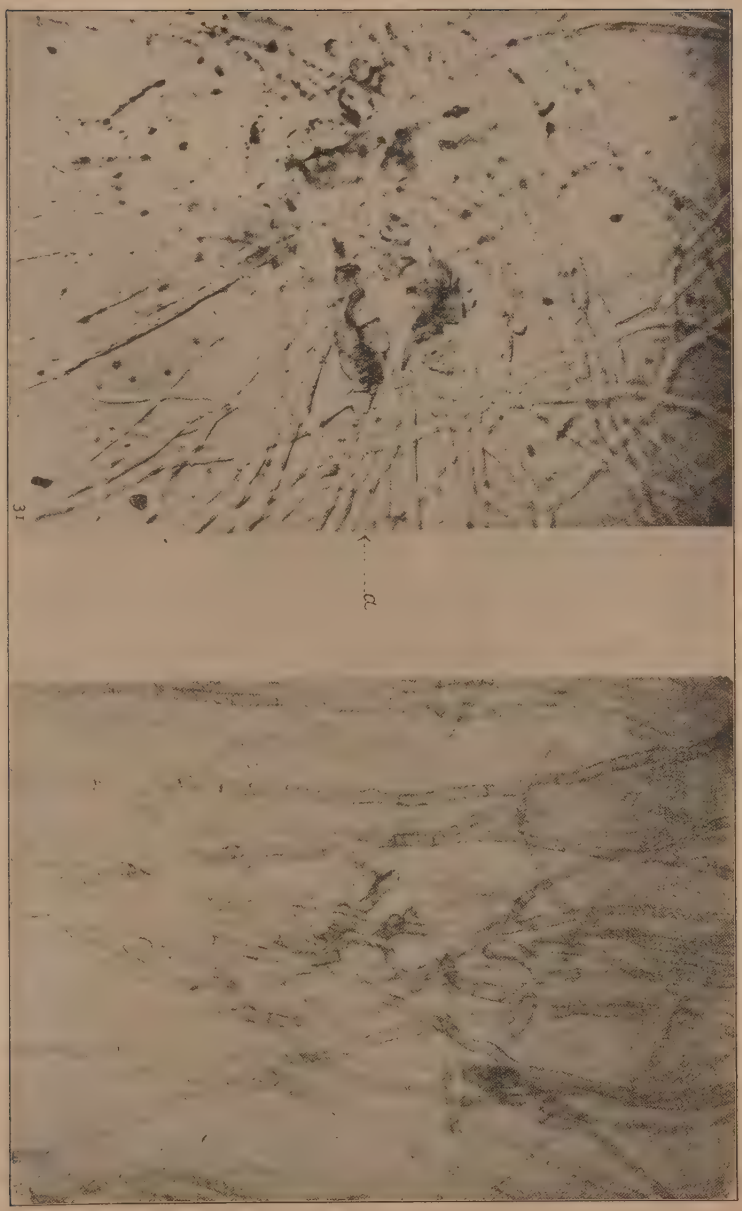
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PLATE I.

PLATE II.

PLATE III.

PLATE IV.

I.M.I.